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ABSTRACT

Developments in electronic technology that have improved and linked together telecommunication and computers are discussed, as well as their use in instruction, implications of this use, and associated issues. The first section briefly describes the following developments: microcomputers and microprocessors, bubble memory, lasers, holography, optic fibers, satellite-to-rooftop communications, videodiscs, charge-coupled devices and the application of electronic technology to communication. The potential of these developments for education is then explored by showing how telecommunications and computers can be used in instructional programs as a source of information, a source of dynamic interaction, or resources for managing instruction. The possible impact of electronic technology on educational aims and content is also discussed, as well as the question of when and where electronic technology will be used in education. A bibliography of 29 items is included. (Author/CHC)

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Future Applications of Electronic Technology to Education

A Resource Paper For A Statewide Conference

THE FUTURE OF EDUCATION IN FLORIDA

February 6, 1979

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Future Applications of Electronic Technology to Education

"New developments in telecommunications and computer technology may be as significant for education as the Gutenberg press," according to the keynote speaker at the first National Conference on Education and the Future in Houston, Texas, (McHale, 1978). We may be moving into a new era in education, but electronic technology does not guarantee improved education. The potential for and possibility that improvement will be realized are explored in this paper.

A number of developments in electronic technology have improved and linked together telecommunication and computers. The first section of this paper briefly describes the following developments: micro-computers and micro-processors, bubble memory, lasers, holography, optic fibers, satellite-to-rooftop communications, video discs, charge-coupled devices and the application of electronic technology to communication. The potential of these developments for education is explored in the second section of the paper by showing how telecommunications and computers can be used in instructional programs. Then, the possible impact of electronic technology on educational aims and content is presented. The paper concludes by discussing the question: When and where will electronic technology be used in education?

Existing and Projected Electronic Technology*

Micro-computers and micro-processors. The history of computer technology has been a fiercely competitive race to develop smaller and more reliable components, faster processors and larger memories. A crucial breakthrough came in the 1960's with the introduction of integrated circuits (IC). Since that time the number of components on an integrated circuit has increased by several orders of magnitude. Whereas in 1970 an IC chip 300,000 times as wide as an atom was capable of processing 100 bits of

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information, today a chip only 1/5 as wide can process 20 times as much information. It is estimated that by 1990 it will be possible to process six million bits of information using a chip only 1,000 times as wide as an atom. In other words, in 20 years, the amount of information processed by a single chip will increase by a factor of 60,000, while the size will decrease by a factor of 300.

In practical terms, this means the functional equivalent of hardware which once filled a room can now be held in the palm of the hand. This has made desk-size micro-computers that include micro-processors, support circuitry and memories possible. Micro-computers can now be purchased for less than $1,000, with the price projected to drop with mass production.

The energy required to operate computers decreases as the size of the IC chips decreases. For example, it is possible to buy a calculator ($34) the size of a credit card and only 1/8 inch thick that will operate for 1300 hours on a small enclosed battery. Eventually it may be possible to operate a micro-computer on the electricity generated by the human body.

By 1985, the increased power of the processor and the low cost of relatively large-capacity memory will enable the micro-computer to support versatile, small, stand-alone systems.

By means of optical fiber and satellite-to-rooftop communications systems now under development (see below) an international multi-computer inter-linked network could be established. Such a network would consist of large computers having extremely powerful processors and large-capacity memories, each computer being located in a center of industry, commerce, research or education. These computers would be designed to handle a wide range of data types and software, and would be inter-linked by a satellite communications system. In addition, each large computer would serve as the hub of a local network. Each local network would consist of individual micro-computers, each located in a house, factory, office or school. These computers would be linked to the central computer either by an optic fiber link or by a satellite-to-rooftop system, depending

upon local conditions. Each local micro-computer could act independently, as a control unit operating the central computer (and from it, to any computer in the world), or through the central computer to any other micro-computer. Such a system would be so powerful that it would make our present libraries and computers look like Model T's.

Bubble memory. One emerging development which promises to revolutionize the computing industry is in the area of data storage capability, or computer memory. In the past, information for computing systems was stored on paper media such as punched cards, or magnetized media such as tapes, discs and "floppy discs." Tape storage was cheap, but relatively slow to access. Disc storage was faster, but fairly expensive. Bubble memory technology promises to provide faster and less costly methods of storing and retrieving data, and it is considered a more rugged and reliable medium than any currently available. Most forms of bubble memory, unlike some storage methods currently used in micro-computing, retain data when power is cut off for a time. Consequently, it is particularly well suited to portable uses.

Texas Instruments is presently marketing a bubble memory unit for about $500. Contained in a thin film sandwiched between a crystal substrate (garnet) and a permanent magnet, the bubble memory is a cylinder about .0001 inches tall and .0001 inches in diameter. This small unit contains about 287,000 magnetic domains, or "bubbles." Each bubble represents one bit of digitally-coded information (0 or 1, depending upon the polarity of the bubble). Altogether, then, the bubble memory unit can store 287,000 pieces of data. Thus, a computer utilizing a bank of bubble memory units would have a tremendous storage capacity, yet would be very small.

Less expensive, more flexible, and more reliable memory will have implications for education through its impact on computing capability in general and through a vast increase in the amount of information stored. Bubble memories are, for example, expected to have widespread use as auxiliary memories for micro-computers. This will improve access to information for instructional purposes through small, inexpensive systems in both the school and home.

A second use of bubble memories which will have a wide-scale effect on educational communications is to control minute "light-cells" on a television screen. Using bubble memory to turn small light cells on and off could produce much higher resolution pictures than with the present vacuum tube scanning system. No scan lines would be produced. Further, the elimination of the vacuum tube would result in a flattened screen, which could be hung on a wall like a painting. Commercial television will probably not benefit from this development, since present equipment investments are so large, and all present equipment would have to be replaced. But the impact on closed circuit television, microform readers, and data transmission devices would be tremendous.

Lasers. The laser (light amplification by stimulated emission of radiation) is one of the newest technological developments to come to fruition. During the early 1930's Albert Einstein theorized that a photon striking a molecule in an "excited state" would release energy in the form of another photon emitted in the same direction. This forms a cascade of photons or "light beams" which is monocromatic, highly dense, and coherent ("in phase") and which can be precisely focused and manipulated. The major application of this phenomenon derives from the needle-like property of the light wave. This coherent light form is currently finding applications in microsurgery, distance measurement, construction alignment, and communications. Future developments utilizing the laser rely on its high intensity, pure frequency composition, and precise, needle-like property. These future developments may occur in the areas of communications, data storage and retrieval, and image processing.

Holography. Through the use of laser beams it is possible to project a hologram. A hologram represents an exact recording of the manner in which an object reflects wave-fronts of light. This recording may be reconstructed with precision through holographic TV and film to form a striking, three dimensional image. Two types of holograms are now projected by common manufactured bulbs: reflective holograms and transfer holograms. Reflective holograms are produced on a cylindrical surface producing the three dimensional image within the space of the cylindrical surface. Transfer holograms are projected in

space--you can walk through or around them.

With no theoretical limit to the size of a holographic image, the possible uses for this new method of imagery are just now being explored. Obviously valuable to entertainment and advertising, the inclusion of holographic forms in educational media will undoubtedly create learning tools more compelling and realistic than previously thought possible. This is assuming that cost will be reduced with mass production.

Optic fibers. Optic fibers for telecommunications involving voice, data, and video transmission are finding current use at a rate exceeding expectations. The fundamental use of optic fibers is transmission of light along nonlinear pathways with minimum energy loss. A simplistic view of optic fibers for telecommunications involves a crystal transducer to modulate a laser beam with electronic data. The laser light beam becomes the carrier through the optic fiber strands, and at the destination utilizes a similar crystal transducer to demodulate the light beam to produce an electric wave form. This technology integrates two new technological developments in the solution of communication problems.

Optic fibers can take the form of plastic strands, but more often are formed from very pure glass strands. Optic fibers have many benefits compared to metal cables presently used. They are smaller, weigh less, transmit signals having wider band widths and have greater information bearing capacity than do solid metal cables of comparable size. For example, only 24 two-way telephone conversations can be carried simultaneously on a pair of copper wires while a single pair of fibers can carry up to 672 two-way conversations. A further benefit is that the signal transmitted via optic fibers is not affected by inductance or other common electrical or magnetic noise sources. Finally, optic fibers are derived from silica, which is a relatively inexpensive raw material and should, given improved processing technology, result in optic fiber systems costing one-half of comparable metal systems.

Satellite-to-rooftop communications. The exchange of messages from one place on earth to another by bouncing signals off a satellite is a technological advance which

has been with us for several years. The concept of satellite-to-rooftop communication is simply employing communication satellites to allow the transmission of information to many receivers. The term "rooftop" implies that an antenna or receiver can be located at any site, including a school, office, hospital, private home or apartment complex. Another possibility is that one large receiver could capture the signals and distribute them to private TV monitors via a cable. These alternatives open up many possibilities for education. Since satellites can transmit radio, TV and digital computer data, they are only limited in the educational services they can provide by the imagination of educators and the availability of funds to invest in the necessary hardware and software. Currently, communication satellites require the distribution of large amounts of information over long distance before they become economical. One positive cost factor is that communication satellites are "distance insensitive." For example, from Washington, D.C., it costs the same to send a message to Paris as it does to send one to Silver Springs, Maryland. Improvements in this technology will no doubt result in greater economies.

Video discs. The invention of video discs represents a significant advance in information storage. These 12 inch plastic or vinyl discs represent a flexible or "floppy" version of the phonograph record. Just as audiotapes have been a cheaper, more compact method of storing audio information than records, video discs offer an inexpensive way to store and retrieve a great deal more video and audio information than possible with previous media. Three hundred books of 250 pages each or 50 hours of high-fidelity music can be stored on a single side of a 12 inch video disc. It is possible to record a classic book in the original form and in a movie version on a single video disc. The first one minute on the video disc would be the book which can be read page-by-page in a single-frame sequence. The remaining one hour and 59 minutes of the disc would contain a motion picture of the book.

The benefits which video discs offer in terms of increased savings and denser storage are accompanied by a greater flexibility of use. It is possible, for example, to:

- "Freeze" single frames, or play back specific parts of the disc, with greater fidelity and at a greater speed than with other media,
- Mix still frames and motion randomly, on a pre-programmed basis,
- Store both video and audio information on the same tape with excellent fidelity for both sound and image.

All these capabilities will be available at a fraction of the cost of conventional information storage, partly because maintenance is minimal since the discs never wear out! Discs are played by either (1) passing a stylus with an electrode over the spinning disc and picking up the coded information electrically, or (2) focusing a laser on the disc, picking up coded information and converting it to sound and pictures optically.

Video disc technology may also be facilitated by other available technologies. Computers can be used to drive a video disc system, thereby making the process more automatic and more reliable.

Learning situations will be enhanced through the storage and retrieval of video signals of high quality at low cost. Individualized instruction, especially programmed instruction, will benefit by facilitating random access (branching) depending on student needs. In addition, video disc technology will have a general impact by decreasing the cost of effective educational materials.

Charge-coupled devices. A new type of semi-conductor, called the "charge-coupled device," has been developed over the past seven years. This device shows great promise for storage, analog-digital conversion, sequencing and counting of electrical pulses. It also has wide application in the field of electro-optics.

The device consists of a layer of silicon, a layer of insulation and a layer of conducting electrodes. At very small local pockets, electric charges are deposited. These charges can be kept separate from each other and can be moved from location to location throughout the device. They do this at a finite speed, which can be varied.

The device is an analog storage unit, but it can be conceptualized as a digital storage unit by defining ranges of voltage for each piece of data. This is useful

because the quantity of charge generated at each local point is directly proportional to the quantity of charge acting as input signal. Seven or eight bits of information can be stored in a computer memory cell, where only one could be stored before. But since charge-coupled devices are much smaller than conventional semi-conductors, by a factor of a hundred, 700-800 bits of data can be stored in the space formerly used to store one bit. And since the charge-coupled devices are much simpler to build than conventional chip memories, such a storage unit for 800 bits of data might cost less than the storage unit for one bit which it could replace.

The optical properties of silicon, coupled with the analog-to-digital and sequential nature of charge-coupling, result in a device having wide application in electro-optics and image detection. At the present time, in fact, such applications are dominating the development of the device. The optical properties of the device result from the fact that light or infra-red radiation, when striking silicon, causes electrons to be emitted. The intensity of the emitted electron cloud is in direct proportion to the intensity of the radiation which struck the silicon. Thus, a matrix of charge-coupled devices can be used to translate an optical, analog signal into an electrical, digital signal. An example of such an application is to be found in television, where such a device could replace the present vacuum tube used to obtain the picture in the television camera. Other applications include use in satellite surveillance devices, slow-scan television and facsimile systems. Cameras for such devices could be greatly reduced in both size and cost, and their reliability would be increased many times.

Coupled with video discs and bubble-memory equipped receivers, complete television systems, libraries of recorded programs, and computer control and retrieval systems could be stored in a teacher's desk drawer.

Electronic technology and communication. The application of electronic technology to communication holds great promise for education in school or at home. As indicated in the description of optic fibers and satellite-to-rooftop communication, the amount and quality of information transmitted is improving rapidly. Perhaps the most important

development for a global communications network is availability of the micro-processor. With a small one-chip micro-processor, the engineer has a lot more control over modulating the communications signal than previously. The micro-processor introduces the techniques of digital switching into the analog world of voice and picture communications. Digital switching makes the old analog/digital converters that were used with the analog switching machines obsolete. Digital microwave radio is a viable method for voice grade communications. Voices can be encoded into digital pulse patterns. This very recent technological breakthrough has already been introduced into consumer electronics. PCM, or Pulse Code Modulation, is a technique the finer record companies use to get higher fidelity on their records. Sony has a digitiser that allows one to record sound as a pattern of digital signals on their Betamax video cassette recorder. From the technical reports, this technique produces a very high quality signal, better than on any of the highest priced recorders which lack PCM. Canada is already experimenting with digital microwave communication to provide low cost telephone service to rural areas.

Will there be sufficient energy to support global communication networks making full utilization of electronic technology? Advances in electronic technology and telecommunications have resulted in a decreasing need for energy for each bit of information stored or transmitted. Of course, there is and will be a marked increase in the amount of information processed. In the future, the use of coal and oil need to be supplanted by a network of solar satellites beaming power back to earth over laser emitted microwaves.

Use of Electronic Technology in Instruction

The use of emerging electronic technology can have a powerful impact on curriculum and instruction, that is, on the plan for providing learning opportunities and the implementation of that plan. The engagement of the learner to receive instruction in part or totally through the use of electronic technology is the focus of this section. The following section considers how electronic technology might influence curriculum.

Instruction, by definition, requires the learner to be engaged with other persons and things. Olson and Bruner (1974) point out that people learn through either direct or mediated experience. "Whether for reasons of economy or effectiveness, schools have settled upon learning out of context through media which are primarily symbolic" (p. 125). The printed word is the primary medium used to engage learners. Edgar Dale developed "the cone of experience." The cone builds from direct purposeful experiences at the base to highly abstract verbal symbols at the top. The experiences, moving up the cone from the direct to the abstract, are: direct purposeful experiences, contrived experiences, dramatized experiences, demonstrations, study trips, exhibits, educational television, motion pictures, recordings and radio, still pictures, visual symbols and at the most abstract level printed verbal symbols (p. 107).

The primary use of technology in education, from the printed word to television, has been to communicate information to learners. Early research dealing with media attempted to identify effects of differences in mediation; for example, spoken versus printed words, color versus black-and-white pictures. "Invariably the emerging generalization has been that no single level of the independent variable is consistently superior and that often the variable is, in fact, inoperative" (Levie, and Dickie, 1973, p. 877).

Stakenas and Kaufman (1977) reviewed research regarding educational applications of instructional radio, instructional television, computer-assisted instruction, computer-managed instruction and programmed instruction. They found these media have been used at all educational levels and in practically all subject matter areas. As to effectiveness, they conclude, "Students learn effectively from all of these media, and relatively few studies indicate a significant difference which favors one medium over another--including comparisons with traditional instruction" (p. 74).

The information dissemination aspect of educational technology might be conceived as a channel used to communicate information to the learner. The nature of the information and when it is delivered to the learner becomes much more important than the

nature of the channel. Accordingly, attention has shifted from trying to find the one best technology to looking for the most appropriate technology for a given task and learner.

Educational technologists utilizing a systems approach have developed a number of instructional development (ID) models. These models support the systematic development of instruction from problem definition through evaluation and aid in the selection of appropriate educational technology. A comprehensive review of ID models by Stamas (1974) includes those developed by Barson, Hamreus, Kaufman, Childs, Banathy, Briggs, Gustafson, Gerach and Ely, Douglas and Kemp. Four features are found in each of these models: " (a) specification of behavioral objectives; (b) information flow between and among the steps (feedback); (c) flowchart or combination flowchart narrative description of the process; and (d) a recycling process which permits a continuous re-examination of whatever is developed to determine the instructional effectiveness, efficiency or relevance" (p. 1)

ID models provide for an analysis of the learning task and, in some instances, analysis of learner characteristics. Based on this information, an instructional system is developed including educational technology appropriate to the learning task and the learner. The ID approach resulted in a more effective use of educational technology.

ID models are best suited to competency-based education with measurable objectives. Advocates of some instructional designs claim they are effective for all of education. Others, such as Briggs (1970), view their models as effective in a systems approach to cognitive development. Briggs recognizes that there are non-systems models that "emphasize 'spontaneous' design of instruction--instruction whose goals and procedures are developed on-the-spot for each learner, who controls both the objectives and methods of learning" (p. 1). Briggs urges, however, that this learning be as systematic as possible.

Of five curriculum designs identified by Saylor and Alexander (1974), two can

effectively utilize instructional development. Joyce and Weil (1978, p. 3) identify four families of models for teaching: behavior modification, information processing social interaction and personal development. Instructional development is very effective for behavior modification and for most information processing approaches. However, it is of little value for social interaction and personal development--models that may become increasingly important in an age of impersonal automation.

Instructional development is an important and powerful tool for many, but not all, educational tasks. Professionals in educational technology have been in the forefront of the development of ID. This has had two important, unintended consequences. First, teachers who reject the ID approach have tended to reject the use of educational technology. Second, possible applications of educational technology to all models of teaching have not been developed. In fact, educational technology can be very valuable in any number of models. Perhaps the greatest application of electronic technology in the future will be for the self-directed learners who apply a non-systems approach for their own development.

This paper explores applications of electronic technology to any instructional approach. The utilization of computers and telecommunications as a source of information is an extension of earlier educational technology. A second type of application is as a source of dynamic interaction with the learner. This was not typically found in earlier technology, although programmed texts provided some interaction. A final application is as a resource in helping to manage instruction. Illustrations of each of these applications are provided.

Computers and Telecommunications as a Source of Information

What it means to be educated has changed throughout history with the technology available and access to it. In pre-literate society, information was passed on in oral form and direct experiences were provided for skill training. The "educated" person knew tribal history and possessed the necessary skills. With the invention of movable type, information began to be stored in a relatively few books--primarily religious in

nature. It was nearly 100 years after Gutenberg's press before reading became a school subject. For many years students copied written material from the board into their notebooks. The educated person was able to recall this information. Later, textbooks became available, and the student was supposed to learn what was in the book. Education today consists primarily of learning from books and from teachers' explanations of what is in books. There are some exceptions; for example, vocational students may have direct experiences with tools and machines.

The development of computers and telecommunications provides vast improvement in the quantity of information available to a learner and facilitates access to this information. The quality of the reproduction of the information has also improved. As a result, the learning center of the future could have a communications console consisting of a high resolution color video monitor and camera, a computer keyboard and data communications arrangements. This communications console--or comsole--could be used for picture-phone communication and as a computer terminal. Vast amounts of information could be stored in the users comsole using either bubble memory chips or charge-coupled devices.

Quantity of information. The sheer quantity of information is growing at an ever-increasing pace. At the rate knowledge is growing, by the time a child born today graduates from college, the amount of knowledge in the world will have increased four times. By the time the child is 50 years old, knowledge will have increased 32 times and 97 percent of everything known in the world will have been learned since the child was born.

The new electronic technology, as has already been pointed out, makes it possible to store vast amounts of information--300 books of 250 pages each on one video disc or 54,000 pictures on one video disc. Donald Bitzer, the developer of PLATO, says he intends to place the entire University of Illinois library in a computer accessible one-inch cube by 1985. If this can be done it will revolutionize the college-level educational system, since students could do most of their library research from home.

The student could dial the data bank that had what he or she wanted on storage, "down load" it into the comsole memory bank, and read it at leisure.

Access to information. Information can be of value to learners only as they have access to it. Joyce (1974) identifies two types of access--linear and random. Linear access "represents a sequential ordering of media types in terms of various functions" (p. 417). For example, entire self-paced, self-instructional curricula can be programmed into micro-computers--including appropriate supportive audio visual materials in a variety of modes. Computers combined with telecommunications suddenly provide access to a great wealth of information. One example is the ERIC system which makes it possible to locate a vast amount of printed material. Another example is an experimental program in England which makes it possible to view up-to-the-minute news on home television sets at any time simply by dialing for the appropriate news. Thus, for example, an individual can dial for the latest news on the Middle East and then dial for the latest scores in the soccer matches. Widespread adoption of this system would mean fewer newspapers, thus saving vast amounts of timber for other uses.

The potential of access to increased amounts of information does not assure access to the individual. Access depends upon the availability of hardware and software and the ability to use it. Geographical areas served are increasing through the use of satellite-to-rooftop communications. Continuing education is one area where great impact from satellite use is contemplated, with educational programs ranging from veterinary medicine to fiscal management, teacher education to physician education, and engineering to law. There have, in fact, already been several very successful educational pilot programs conducted. For example, the ATS-6 Satellite program (Tele-Education Medicine) utilized satellites to provide educational TV program services to the Rocky Mountain Region, Alaska, and the Appalachian area. Educational services included career education and teacher training. The same system provided for Tele-medicine which furnished two hours per day of medical TV programming in addition to voice/data communications for vital-signs transmission and emergency medical information

channels. The number of time-sharing computer systems in schools and colleges has increased to the point where "the total number of simultaneous users served by the hundreds of systems throughout the country is counted in the thousands. With continuing sales to schools and colleges, this number will expand to the tens of thousands" (Zinn, 1978, p. 71). Zinn also sees a rapid increase in the number of personal computers sold from nearly a half million units sold during 1978, until in a few years the number will be counted in the millions (p. 71). Computer companies are developing micro-computers and software for use in homes and businesses. Zinn forecasts that, "Personal computers will bring about qualitative changes in education within the home and perhaps in educational institutions as well" (p. 71).

A nagging question remains. What will happen to children who grow up in homes without a micro-computer? We already know that children growing up in homes with little or no print tend to have more learning problems. Will the presence or absence of a micro-computer widen the gap?

Quality of information. Dale's cone indicates that the quality of an instructional engagement improves as the material utilized approaches a direct experience. Imagine, for example, how much the effectiveness of this paper would be improved with illustrations and further improved with accompanying demonstrations. It would be most effective if supplemented or replaced, with a series of hands-on experiences by the learner.

Computers coupled with telecommunications have improved the quality of presentation of information by becoming more direct and closer to the real experience. For example, television relayed through satellites can show events around the world as they are occurring. For another example, consider the holographic capabilities provided by lasers. Anyone who has viewed Michaelangelo's statue of David recognizes the futility of describing it in words. Photographs of the statue capture some of its serene beauty. In the future, a student studying art will be able to view Michaelangelo's David, three dimensionally, either at home or in the classroom.

New electronic technology enables us to view objects in greater detail. For example, the use of lasers with optic fibers provides a totally new aspect to medical diagnosis. Whereas medical students in the past learned to diagnose physical aberrations by looking at x-rays, now they use endoscopes composed of optic fiber strands connected to a TV monitor. The scope is inserted through various orifices of the body and the student can study and diagnose the body from the inside. The image of the organ, veins, and other internal parts appear in color on the television monitor as the endoscope moves through the body.

Computers and Telecommunications as a Source of Dynamic Interaction

Typically instructional media, whether print, pictures, audio tapes, motion pictures or television, have presented information to learners. Advanced technology is now able to provide for a dynamic interaction between the learner and the source of information--an interaction where the response of either the learner or of the media influences the reciprocal response. For example, computerized modules for the teaching of arithmetic provide for a diagnosis of the learners' capabilities and presentation of new material based on this diagnosis. Each response by the learner influences subsequent material presented to the learner. One advantage of the computer is its remarkable "patience" in interacting with learners.

Computer games provide for interaction whether it is playing ping pong on the television screen or playing chess with a computer. Computerized games will provide the first direct contact with a computer for many individuals and will accelerate the spread of computers. As a result of playing computer games, a mind set of "beat the computer" develops which may need to be overcome as individuals learn from computers.

Business and medical schools are making effective use of computers in the simulation of case studies. A group of business students can learn that through a series of poor judgments a computerized "business" can go "bankrupt." Medical students, through a poor diagnosis of a simulated illness or through improper prescriptions, can learn valuable lessons without the loss of life.

One of the most dramatic uses of computerized simulation is in the training of pilots and astronauts. For example, Eastern Airlines trains pilots for their 747's on a multi-million dollar simulated plane. Student pilots learn that with one engine gone, they can still pull out of an improper landing approach. They also learn to pull out with icing on the wings. But, when they attempt a pull out when their simulated plane has an engine out and icing on the wings, the altimeter continues to drop, suddenly there is a sharp jolt to their cabin, the lights black out to be replaced by an ominous red glow. Pilots are not likely to forget this simulated crash.

Micro-computers can be programmed to permit creative endeavors which allow the student individual input. For example, a student studying music composition can write the melody, punch up various combinations of instruments and hear the composition played. Through computers it is also possible to create pictorial art forms on a television screen.

Telecommunications and computers do not allow for human, one-to-one interaction. Micro-computers could, however, be hooked up to an educational telephone system, thus enabling non-visual communication at specific times between the student, other students and the teacher. This can eventually be improved on with the image phone lines which give visual imagery. The satellite could provide students the opportunity to hear internationally famous people speak to them live over television with telephone communications providing question and answer capabilities. The MacNeill-Lehrer report on the Public Broadcasting System demonstrates some of the capabilities of instantaneous telecommunication. Through the use of satellites, it would be possible to have a global seminar of international experts considering such topics as world hunger.

Computers and Telecommunications as Resources for Managing Instruction

Contemporary uses of computers to manage instruction include scheduling students, maintaining student records and generating test items. Computerized learning modules provide a pre-test of students, presentation of a variety of materials in an interactive

mode, monitoring of progress and a summative evaluation of the experience. In the future it will be possible for a computer program to analyze a student's learning style, prescribe learning material appropriate to the style and present the material to the student.

The use of computer learning modules for training and retraining employees is expanding. Executives find that the diagnostic capabilities of a computer program make it possible to start at the level of knowledge of the employee and enable the employee to learn the material at his or her own pace. This saves the employee's time and thus saves money.

One of the most valuable future uses of a computer telecommunication network will be to foster self-directed learning or self instruction. One avenue will be through the utilization of computer programs. However, as the following illustrations show other uses will be possible.

A national conference on the future might be organized utilizing a computer program. In advance of the conference, each participant would select areas of special interest; for example, energy and the future. The preferred style of learning for each individual would be mapped by a computer as participants indicate their interest in reading, hearing lectures, viewing films, participating in discussions, interviewing experts, viewing demonstrations, etc. The individual participant would be given a pre-test to determine the present level of knowledge regarding energy and the future. This computer derived and analyzed information would enable the organizers to structure learning experiences for the conference. Each participant upon registration would be given a program showing activities and a computer print-out suggesting sessions of greatest value and interest to him or her. This might include, for example, viewing films, participating in group discussion with experts and visiting a solar energy installation.

Learners could be self-directing in their learning at a comsole (see page 13) either in the home or at a learning center. As another illustration, assume that an individual planning a trip to New Zealand wishes to gain some advance knowledge of the

country. As a first step, the individual would indicate to a computer his or her primary interests in visiting the country; e.g., to see the natural attractions, to study the people, to study the art, to investigate the possibility of retiring or studying in New Zealand. Preferred learning styles would also be indicated; e.g., reading, viewing still pictures or moving pictures, hearing lectures, etc. Based on this information, the computer would provide a listing of material available with a brief description of the material.

The individual could then interact through the comsole with the material selected. This could include such varied activities as reading books on New Zealand, hearing lectures, viewing movies of scenic locations, watching video-taped interviews with Maori craftsmen, viewing holographs of art from New Zealand, studying trend lines of indicators of New Zealand's economy, reading current news and viewing New Zealand telecasts.

This brief review would substantiate McHale's (1978) assertion that new developments in telecommunications and computer technology may be as significant for the future of education as the Gutenberg press. The impact of this technology will depend upon the resolution of a host of economic, social and political issues. It will also depend upon humanity's imagination in devising creative and constructive uses for these powerful tools.

Issues Associated with the Use of Electronic Technology in Instruction

1. How can teachers learn to make use of electronic technology in their instructional programs?
2. In a society where information is power, should all citizens be assured of access to electronic technology providing ease in the gathering and use of information?
3. Where the total volume of information doubles every few years, how can we select what is to be experienced or learned? Having too much information available can be a problem, just as too little.

Implications of Electronic Technology for Aims and Content of Education

Reading was not one of the basic skills before Gutenberg invented movable type. The need to read expanded with the availability of printed material. For centuries the ability to read was an advantage enjoyed by a small and powerful elite; it still is in many developing countries. During the last century in our country it was recognized that one way to keep people in subjection was to deny them an opportunity to learn to read. It is only during the last few decades that industralized nations have recognized the need for all citizens to be literate.

The commercially produced, sophisticated computer is only 30 years old. However, its use has expanded so rapidly that already the lack of computer literacy is being referred to as "The Next Great Crisis in American Education" (Molnar, 1978). Molnar, of the National Science Foundation, points out, "Our economy is in a period of significant and fundamental change...from the production of industrial goods and services to a greater emphasis on science and knowledge-based industries" (p. 35). The great influx of information makes mandatory the use of computers to store and process data. Molnar (1978) argues, "Computer literacy is a prerequisite to effective participation in an information society and as much a social obligation as reading literacy" (p. 37).

Already we are witnessing a growing separation between those working creatively with computers and the rest of the population. A new elite is emerging in a world where knowledge is power. Some individuals are attempting to reduce this gap. For example, a researcher in cardiology is finding time in his busy schedule to take courses in computer science, "So I can talk with the computer scientists who work for me."

Each technological development in education has in the past had the effect of discriminating against large segments of the population who were unable to gain access. In a world where many homes have little or no reading material, we are suddenly confronted with the possibility of consoles in some homes. Although our

society cannot provide comsoles in every home, any more than books, we should assure every citizen has an opportunity to learn to use the new technology.

Our children are growing up in a society with "clip-on-skills"--today the calculators, tomorrow personal micro-computers. How can learning to use these new tools be added to an already full curriculum? Can something be replaced? Molnar (1978) states, "Computers and hand calculators have made obsolete many subjects and have relegated the calculation of square root, logarithms, and fractions in education to the level of importance of dipping candles and tanning hides" (p. 36). He reports on a meeting of educators convened by the National Science Foundation in which a leading author of elementary school mathematics texts observed that the first six years of mathematics in our schools is devoted to learning the four basic functions of addition, subtraction, multiplication and division. He asked, "If we introduce into the first grade calculators which automatically perform these functions, what will the children do for six years?" (p. 36).

Education appropriate to a technological society will recognize the distinction between information and knowledge. Computers can store vast amounts of information. Humans develop knowledge from this information as they use it to solve problems. In the past, students have been expected to store information; in the future, the emphasis will shift from having actual possession of information to the process of having access to it. Accordingly, education will lessen rote processes for remembering data in favor of developing the ability to engage in analytical thinking. Students will need to learn how to use technology in order to have access to information.

If we are to avoid Orwell's thought-control world of 1984, citizens of all ages need to maintain a balanced view of technology. Technology will probably not overpower and possess us, neither will it save the world from ignorance and injustice. A technology is a collection of tools--instruments of and for men. These tools have no power by themselves, they only amplify the power of the individuals who use them. Travers (1973) points out that historically groups in power use technology to dominate.

For example, the invention of printing with movable type achieved success because of its service to the religious-political estate. Travers adds that, "The religious estate was immensely strengthened by the control it could now exercise over the ideas disseminated by the new invention" (p. 984). Travers points to a contemporary parallel development in that government views the new technology, "to be the instrument of achieving the traditional goals of education more efficiently, in more people, and, ultimately at less cost to the government" (p. 984). He adds that, "The political goals to be achieved...were to be much like the political goals of earlier power-group sponsored technologies, namely that of maintaining the status quo" (p. 984). Travers argues that, "The present trend in educational technology is clearly to bring the pupil under the identifiable stimulus control to the highest degree possible" (p. 989). He cites the Individually Prescribed Instruction (I.P.I.) as "an extreme form of the phenomenon to which reference is made" (p. 989).

The danger, as Travers warns, is that technology will give groups and individuals power over others and ultimately over their own consciousness. Huebner (1974) warns that, "Technology becomes dangerous when it no longer works together with the imagination of the people who use it, but acts instead as a substitute for their imagination" (p. 394). The technology to be feared the most in our society is the one that is understood the least. In ignorance, we live in danger of being dominated by technology and those who control it.

Electronic technology is value-free. The same console that can bring an operatic performance into your living room through holography can also bring hard-core pornography. There will be far more options available for the use of leisure time. The ways in which those options are exercised will directly affect the nature of the programs made available. Education can help to develop discriminating tastes.

Issues Associated with Aims and Content of Education

1. Shall all students be expected to gain computer literacy, or only a select group? Should an understanding of the uses and applications of computers and their effect

on individual lives be required of all high school graduates?

2. Does the computer make some curriculum contents obsolete? If so, who should determine what should be eliminated?
3. Does education have a responsibility for improving the public's taste in programs presented through electronic technology? If so, how should good taste be defined and by whom?
4. How can we avoid the serious dangers of misuse of power that accompanies powerful technological tools for education?

When and Where will New Developments in Electronic Technology be Used in Education?

The preceding sections describe various uses of computers and telecommunications in education. When will this technology be used and in what settings? Answers to this question will depend on the relative cost of using new technology, educators' attitudes toward the technology and the possible development of new delivery systems for education.

Given the financial future facing education (Lewis, Harrison, Soar, 1978, p. 12) the chance of adding electronic technology to the taxpayers' bill is slight unless something can be subtracted. In a study of the cost of educational technology, Kincaid, McEachron and McKinney (1974) conclude that, "With present knowledge even a zero-cost technology might save a school system at most 11 percent of the total budget, and current uses of technologies would save considerably less, if anything at all" (p. 43). Costs for computer-assisted instruction have been reduced since this four-year-old study was published. However, a more recent study, Stakenas and Kaufman (1977) still conclude that, "The upper limit of cost savings to be achieved through applications of hardware-based technology is estimated to be no greater than 11 percent of the total cost of elementary and secondary school expenditures" (p. 77). Note that both of these studies referred to the use of technology in schools.

The use of electronic technology can cut costs of education in schools if it

results in a significant reduction in the number of educational personnel serving a given number of students. The typical school district spends approximately 80 percent of its budget on instructional personnel and less than 10 percent of its budget on material. Clearly, the only way to free funds for electronic technology will be to reduce expenditures for teachers. Such a move will be resisted by the organized teaching profession.

Teachers have been reluctant to adopt new technology for several reasons. It threatens their job security and it means a change in their role. In a school system making full use of computers and telecommunications, some teachers would be employed to develop software. Other personnel would provide direction to students and monitor their work including diagnosing learning difficulties, assigning work, evaluating progress and counseling students. Still other personnel, with a different preparation, would provide group activities fostering socialization of youth. These activities could be centered around problems in the community. Inter-age mixing could be one feature of these groups. Successfully filling these new roles would require teachers to learn new skills and change well-established and traditional patterns of behavior. The failure to make effective use of educational television in schools is indicative of the difficulties that may be encountered.

Early and wide-spread use of computers and telecommunications in schools does not appear likely. The Chairman of the Board of Control Data Corporation (Norris, 1977), one of America's largest producers of computers and related electronic hardware, made the following forecasts concerning the adoption of computer-assisted instruction (CAI):

1. Training for Industry. The most urgent need in industry is productivity improvement. CAI has reached the stage of development where it is cost effective for many types of employee training. "Expenditures for training in industry in the U.S. are estimated at $100 billion annually" (p. 452). Thus, there is a market sufficient to support a national network of learning centers delivering training to industry. Control Data already has such a national network with 26 centers.

2. Special Education. "The next area where CAI will become cost-effective is in special education, which today is very costly" (p. 452). Norris points out that computers have infinite patience and are private.
3. Vocational Training. "CAI will become cost-effective for those areas of vocational training where simulation can replace hands-on experiences within the next year or two" (p. 452).
4. College. Norris forecasts that CAI will become widespread in colleges over the next five years. Norris bases his view on decreasing costs for technologies (decreasing by about 5 percent per year, coupled with a 10 percent improvement in performance) while the cost of instruction in colleges is increasing approximately 13 percent annually (p. 452).
5. Continuing Education. CAI is particularly valuable in keeping up with the rapid generation of new knowledge.
6. Primary and Secondary Education. "Cost-effectiveness in secondary and primary education will occur last of all, yet CAI has important advantages that make it desirable to begin in a modest way immediately" (p. 452).
7. Developing Counties. An international learning network offers advantages to developing countries.

The forecast proposed by Norris does not include computer use in the home. This application is already over the horizon and will provide a large market for CAI in a relatively short time.

A number of educators reacted to the forecasts by Norris (Educator Reaction, 1977). Some expressed concern with his implied assumption that the primary responsibility of education was to be a cost-effective, uniform system to meet immediate job-market requirements. Tyler, though recognizing the value of CAI, points out its limitations in promoting maturation, developing confidence, providing meaningful rewards and helping with transfer (p. 455). The difficulty of securing teacher support was indicated as a block to the use of CAI in schools.

A major block to the use of CAI in schools will be the development of acceptable software. Well designed computer programs require a large investment of time and careful testing. Programs need to grow out of a research base and formative research (Barbatsis, 1978, p. 400) needs to be conducted to improve them. Failure to develop effective programs will result in disconnected micro-computers stored next to TV sets in teachers' closets.

Effective and efficient utilization of electronic technology in schools will require some restructuring of the organization of schools. One of the greatest constraints to making such changes is our inability to break out of old mind sets. A parallel development in transportation illustrates this point. Why didn't railroads develop the airline industry? One reason is that they viewed their mission as running railroads. Had they viewed their mission as transporting goods and people, they might have been in the forefront of the airline industry. Even then the problem of union "featherbedding" would probably have blocked them. It would be difficult to make the airline business pay if every airplane had to have a brakeman and a fireman.

Public school people are not likely to consider alternatives until they view their mission as educating people instead of running schools. Further, employees will need to become more enlightened concerning their true self-interest than is now apparent if education is to keep up with technology.

The development of electronic technology will continue unabated. At the present time schools are being by-passed in the action. It is instructive to read journals on electronic technology and discover the extent to which micro-computers are being developed and marketed for use in the home and in training employees in business and industry. One popular publication is entitled: Interface Age: Computing for Home and Business Applications. Computer companies have written the schools off because "they aren't interested and, besides, they don't have any money."

One consequence of this development may be that private business will take over more and more education. As micro-computers become common, parents will be offered

educational software for their children. In an age of concern for fundamentals, there are probably millions of parents willing to buy computer software for their children. This software, developed by private companies, could be subsidized by advertisers. Unless private industry is more successful in developing computer software than in their earlier attempts at producing educational materials, the market will be flooded by poor programs.

Many parents will not be able to afford either the hardware or software. The educational gap and the occupational/social status gap that follows, between the affluent and the poor will spread even further. The hazards to our society of this educational gap were pointed out by John Dewey (1900) at the turn of the century. "What the best and wisest parent wants for his own child, that must the community want for all of its children. Any other ideal for our schools is narrow and unlovely; acted upon, it destroys democracy" (p. 7).

An alternative future for the application of electronic technology to education is to create a "learning society" with two major components: 1) varied opportunities for citizens to learn and, 2) citizens who, because they know how to learn without instruction, will utilize opportunities for learning.

Electronic technology will open up vast new possibilities for learning. To make effective use of these possibilities, as well as others, a network of learning systems will need to be established. Such a network will include schools as one very important element but will include a variety of other learning centers such as homes, museums, libraries, community centers, businesses, etc. Such a network would be coordinated by a board of education (formerly a school board) and be headed by a superintendent of education (formerly a school superintendent).

To illustrate how a board of education might function, consider how they might provide access to computers for all citizens. The board would establish a central data base and make a collection of software. Homes that wished to make use of this data base and check out software could do so providing they would make their terminal

available two hours per day to citizens from outside the home. If external usage of the terminal dropped below a fixed minimum, charges would be made for software and data. Similar arrangements could be made with businesses. Enough additional learning centers would be developed, in conjunction with libraries, museums, community centers and schools, to serve the population.

An alternative way to organize these centers is suggested by Joyce (1974). Skills centers would assess students' communications and other basic skills and then refer them to appropriate instructional systems and tutors. The skills center would include training in the use of the electronic technology used in other centers. Academic centers would be devoted to the humanities, aesthetics, sciences and mathematics. Survey courses and inquiry courses would be provided. The performing arts centers would provide opportunities to perform in music, drama, television, film production, dance and athletics in a network of laboratories, workshops and little theaters throughout the community. The social ecology centers would be devoted to the process of improving society. Finally, idiosyncratic centers, staffed with counselors and facilitators would serve the students on their own terms.

Having opportunities for learning is not enough; citizens need to use these opportunities. For example, at the present time, many citizens do not view education TV programs. Worldwide attention was focussed on the importance of continuing learning throughout life by the UNESCO report "Learning to Be" (Faure, 1972). This report stresses the difficulties individuals have in adjusting to the many rapid changes taking place in their society and work. Because it is virtually impossible to anticipate and plan for changes that will take place, the only adaptive mechanism people have for adjusting and coping is their ability and interest in continuing learning. The UNESCO report says that, "Education is and will be more and more a primordial need for each individual" (Faure, p. 161).

Bloom (1978), commenting on the UNESCO recommendation for continuing learning throughout life, says, "If schools weaken or destroy this potential for further

learning, the individual will lose the basic tools for adapting to rapid change, and there will be serious negative consequences for the individual and the society" (p. 575). Bloom goes on to recommend that schools ". . . develop a strong positive interest in learning and some of the basic skills in learning to learn" (p. 575). Stated simply, the task of the schools is to produce a learning society, not a learned society.

How well are the schools fulfilling this task? Bloom (1978) says that adult education studies show, ". . . that we do much to develop these continuing learning attitudes and skills in our 'best' students" (p. 575). Bloom adds, however, that for a "sizable proportion of our students, schooling and further learning (in or out of schools) is painful or dull and to be avoided as soon as one has reached school-leaving age or has completed high school or college" (p. 575).

The basic basic, the primordial need for each individual, is to learn how to learn. How can schools be more effective in teaching this basic? Raven (1977) suggests that the ability to learn without instruction involves:

1. An interest in finding out about new things and enjoyment in doing so.
2. Seeking the information needed to help one tackle one's own problems--not someone else's.
3. Reading (collecting information) with a purpose and discarding all things that do not relate to one's purpose.
4. Making one's own observations, collecting one's own data, and systematically testing one's ideas (p. 461).

Note how useful computers and related communication technology would be in relation to these four goals.

Issues Associated with the Application of Electronic Technology to Education

1. How should the costs of applying electronic technology to education be met? By individual families? By educational entrepreneurs? By community organizations? Through tax funds? Should the costs be met by some combination of the above? If so, how can efforts be coordinated?

2. Adapting to a rapidly changing society will require self-directed learning. How should schools and colleges evaluate their effectiveness in developing self-directed learners? To what extent are present methods of teaching and evaluating the basic skills antithetical to producing self-directed learners?

These issues should be resolved in light of the changing relationship between society and education--"conceived as a process of close interweaving between education and the social, political and economic fabric which covers the family unit and civic life" (Faure, 1974, p. 163). All citizens should have the means of learning, training and cultivating themselves freely available. Citizens' relationship to their own education will change so that a sense of responsibility will replace a feeling of obligation. "This movement is irresistible and irreversible. It is the cultural revolution of our time" (Faure, 1974, p. 163).

Electronic technology is a tool that if properly applied can help us create a learning society. Let us use this technology to work with the imagination of the people who use it, not as a substitute for their imagination.

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